

Vibration Basics

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RE Mason

Operational Challenges of Today

‘Our target is zero unplanned downtime’

- Maximize Equipment Availability & Reliability
 - Plan ALL Maintenance - HOW?



‘We are trying to be competitive today with a plant that is typically **more than 40 years old** - and so are our competitors.’

- Extend Machinery Life & Rebuilds

‘We are running our equipment **beyond its design capacity** to handle the variety of materials that we must process’

- Increased throughput without RISK of machine failure?

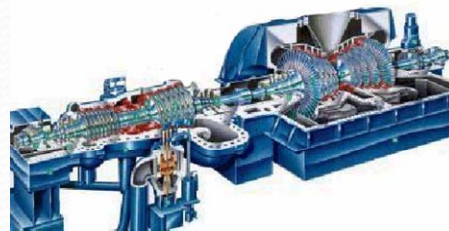
Answer These Tough Questions...

What maintenance does the machine need during the next planned shutdown?

- Do I have the parts, do I have the people ?

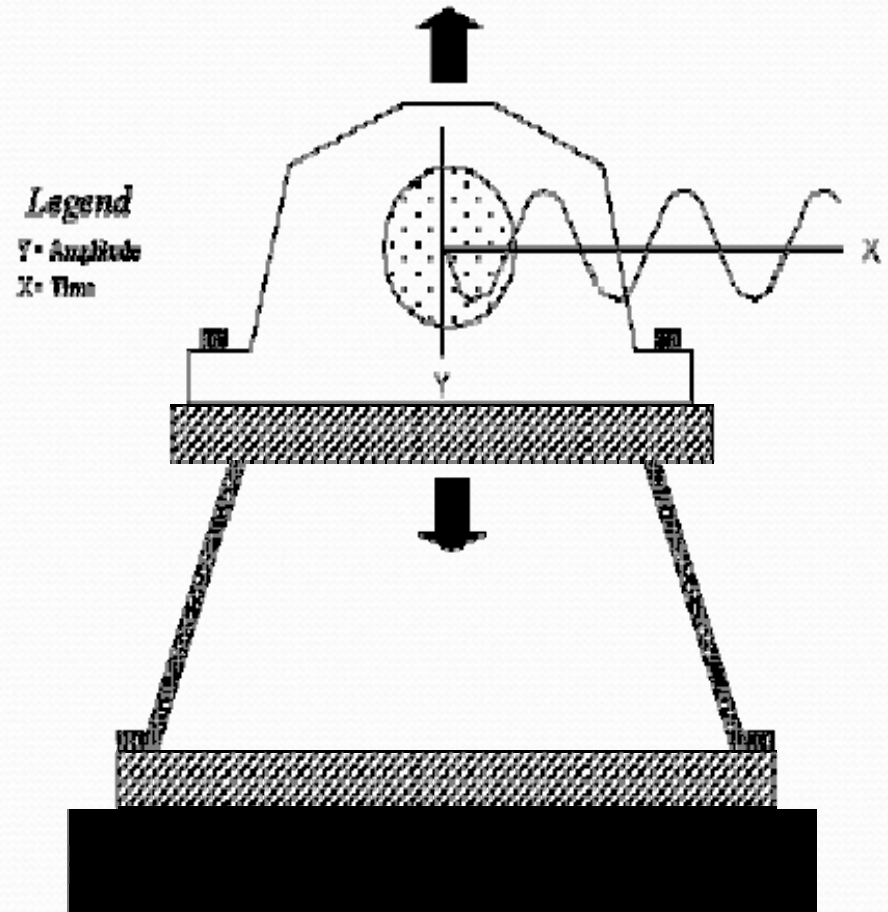
Can the equipment run beyond the next scheduled outage?

- What work can I safely schedule out until the next shutdown?



What is Vibration ?

- Vibration – The motion of a body about a reference point
- At its simplest, vibration is displayed as displacement over time



Why Use Vibration Analysis?



"Of all the parameters that can be measured non-intrusively in industry today, the one containing the most information on machinery health is the vibration signature."

Art Crawford

Acknowledged expert
in the field of
vibration analysis

Overall Versus Spectrum

- Overall can let you know that there is a problem
 - “Hey Fred, something is wrong with your car!”
- Spectrums can tell you what the problem is
 - “Hey Fred, your water pump is bad!”

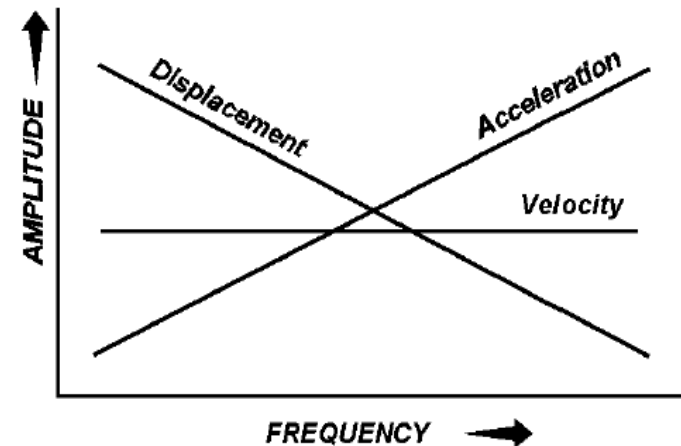
The Units

Displacement accentuates
the low frequencies - Mils

Acceleration accentuates
the higher frequencies
(g's)

Velocity is consistent across
a larger range of
frequencies

Most vibration is
analyzed in Velocity since
the energy level is
consistent throughout the
frequency range.



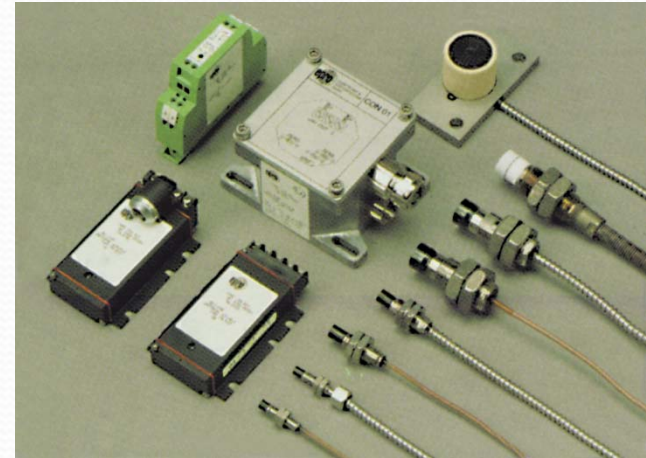
How do we measure vibration?

- Three types of sensors
 - Displacement, Velocity, Acceleration
- Signal processor of some type (CSI 2130)
 - Local or portable display for field analysis
 - Remote
- Software for viewing and storing collected vibration data

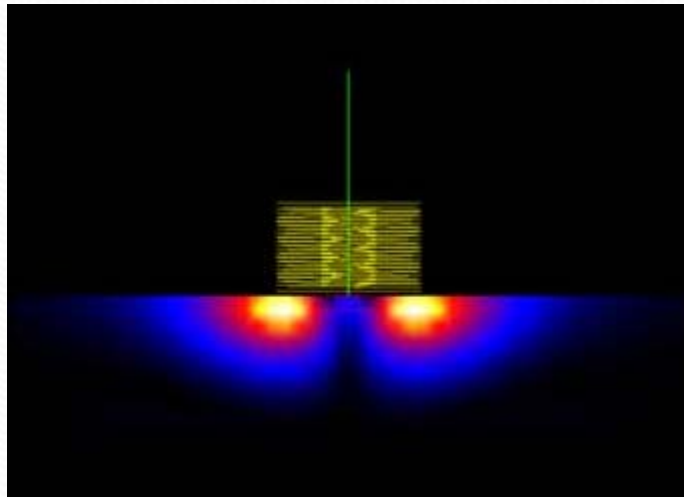
Displacement Probes

Typical Applications

- Sleeve bearings
- Most turbine and large motor driven machinery
 - Main turbine generators
 - Boiler feed water pumps
- Applications in which 'X-Y' data is required for measurements such as
 - Shaft centerline from DC gap data
 - Orbits from vibration data
- Not practical for bearing or gear analysis



Electromagnetic Induction

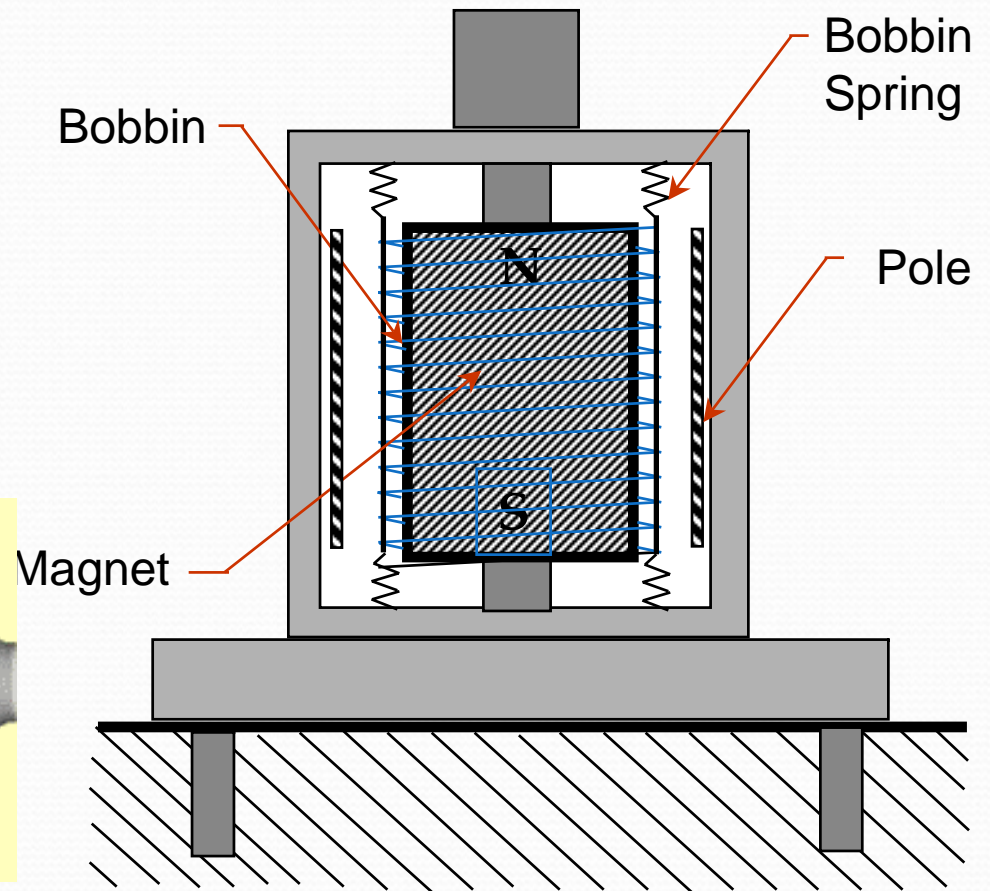
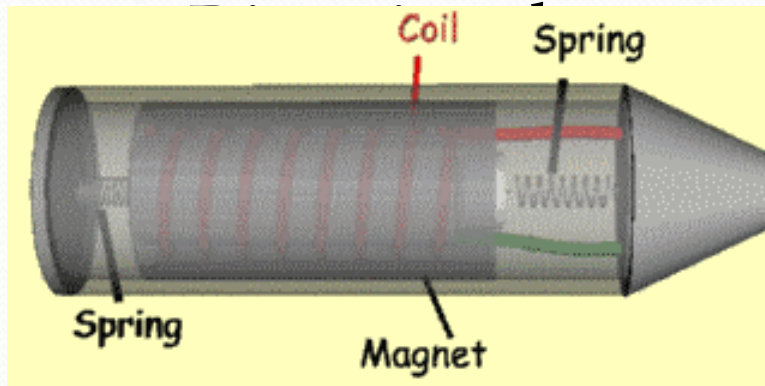


Velocity Pickup

- Velocity Sensor Application
 - Mounted on case of machine or shaft riders
 - Used on sleeve and roller bearings depending on the application
 - When integration to displacement is required
 - Hi-temperature
 - Up to 900°F or higher

Theory of Operation – Velocity Pickups

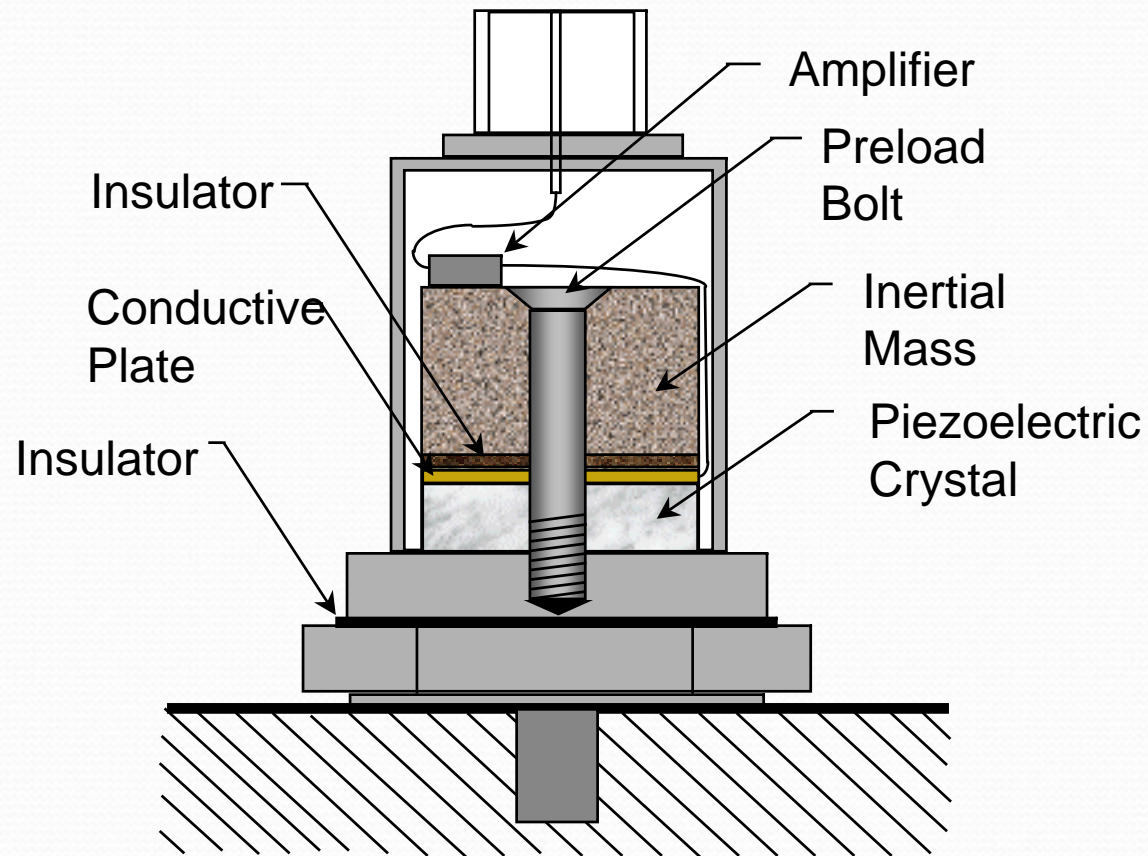
- Mechanical
 - Moving coil
 - Self-powered



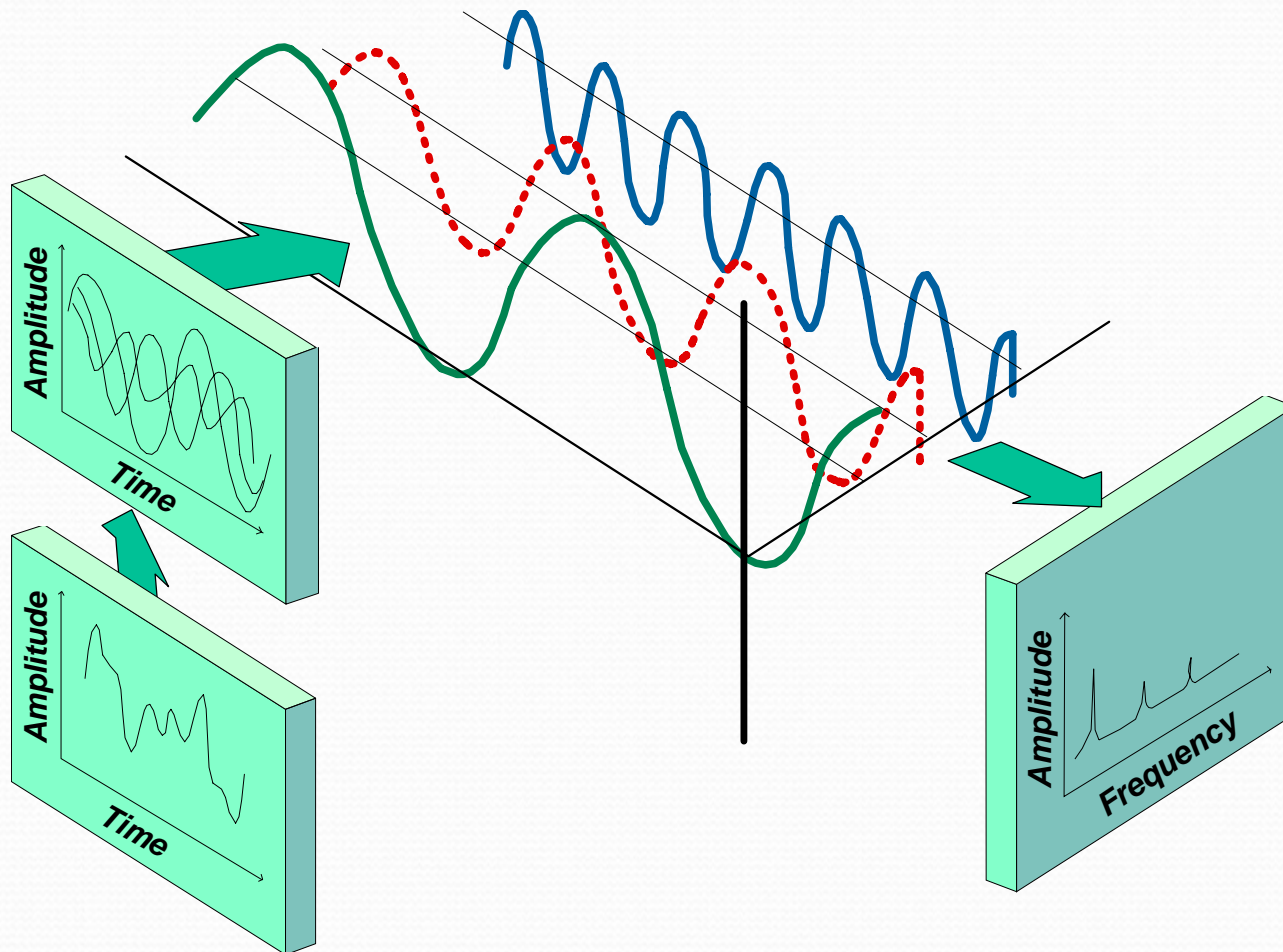
Accelerometer

- Accelerometer Applications
 - Case mounted or magnet mounted
 - Primarily Roller-element Bearings and Gears
 - When analysis and diagnostics are important

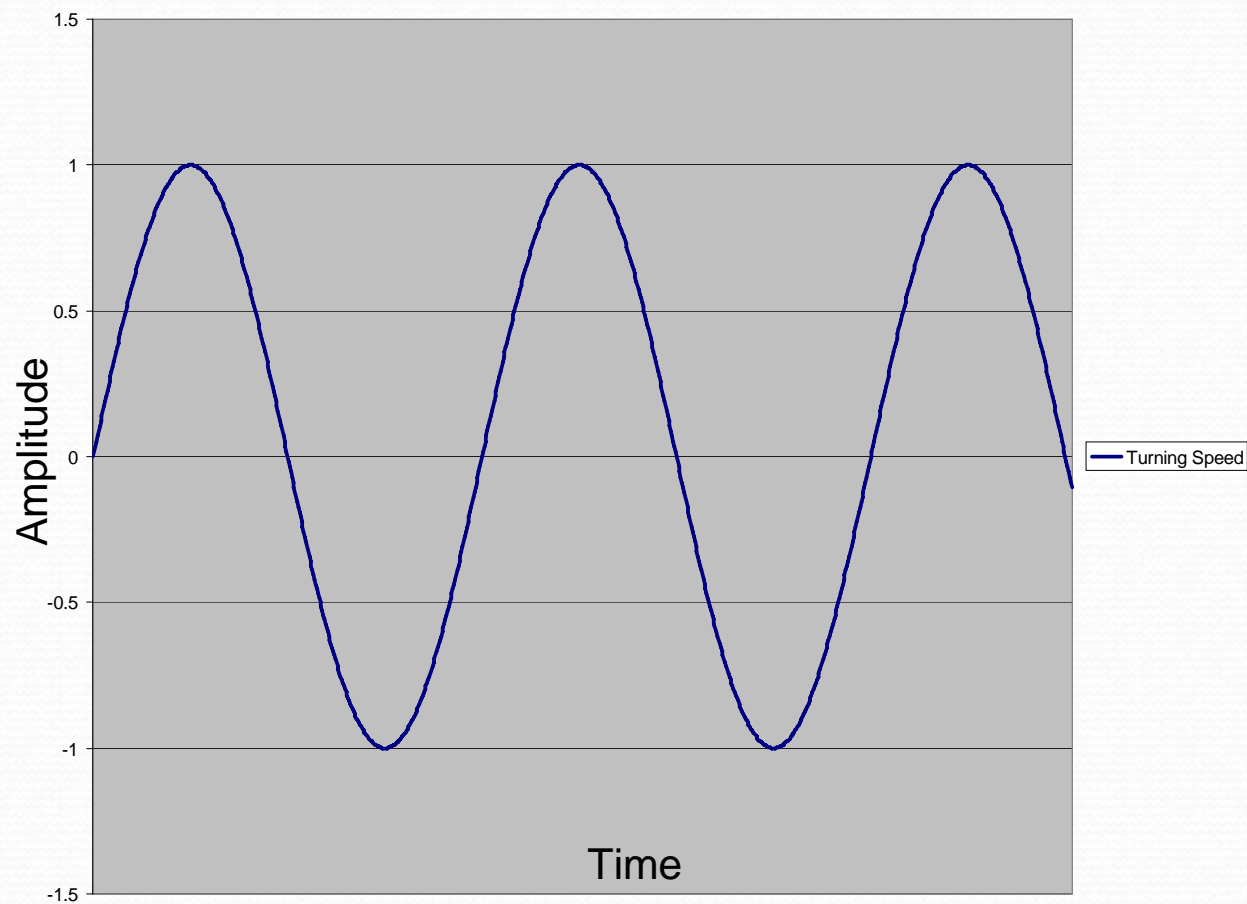
Accelerometer



FFT Signal Processing

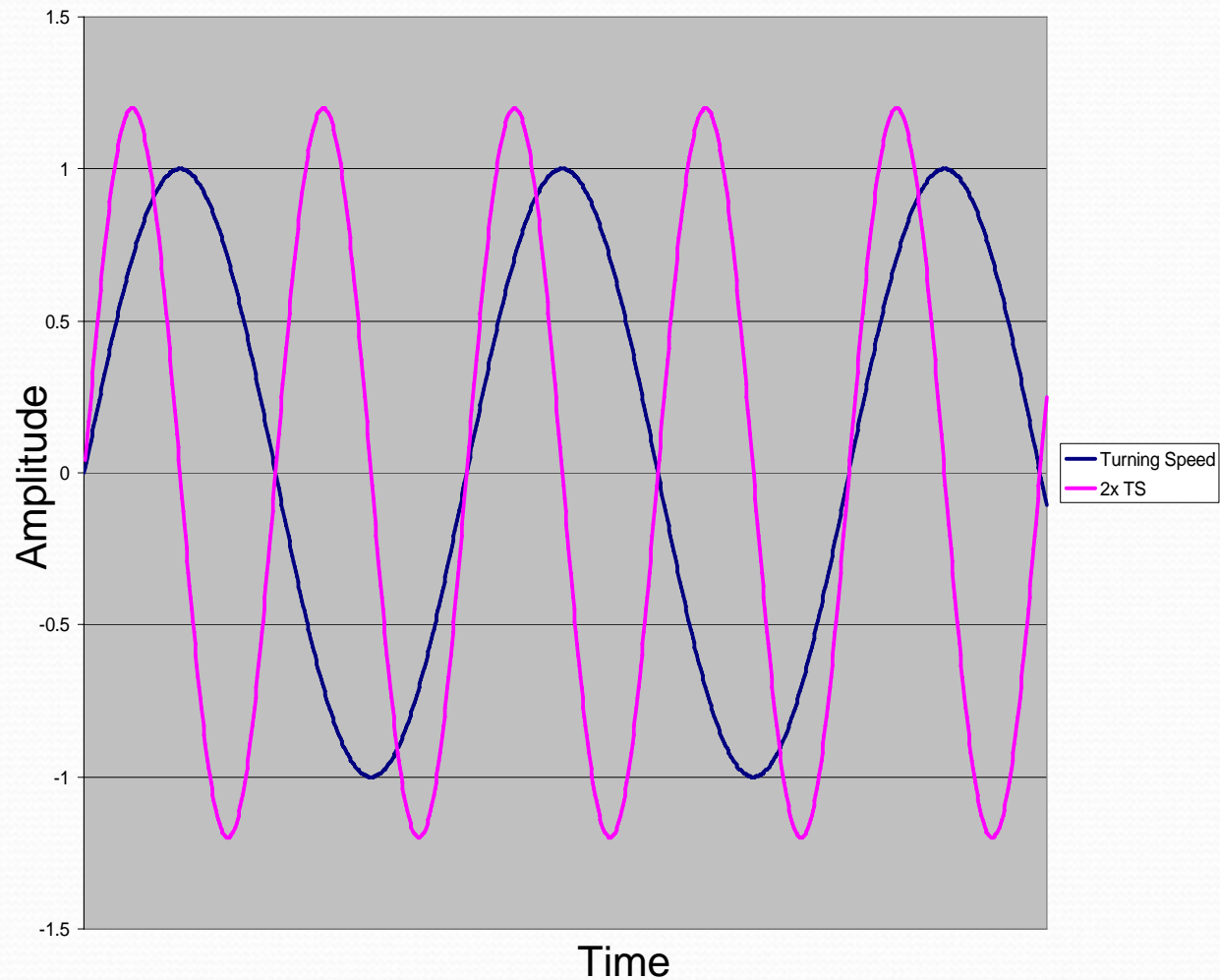


Signal Processing – The Mystery



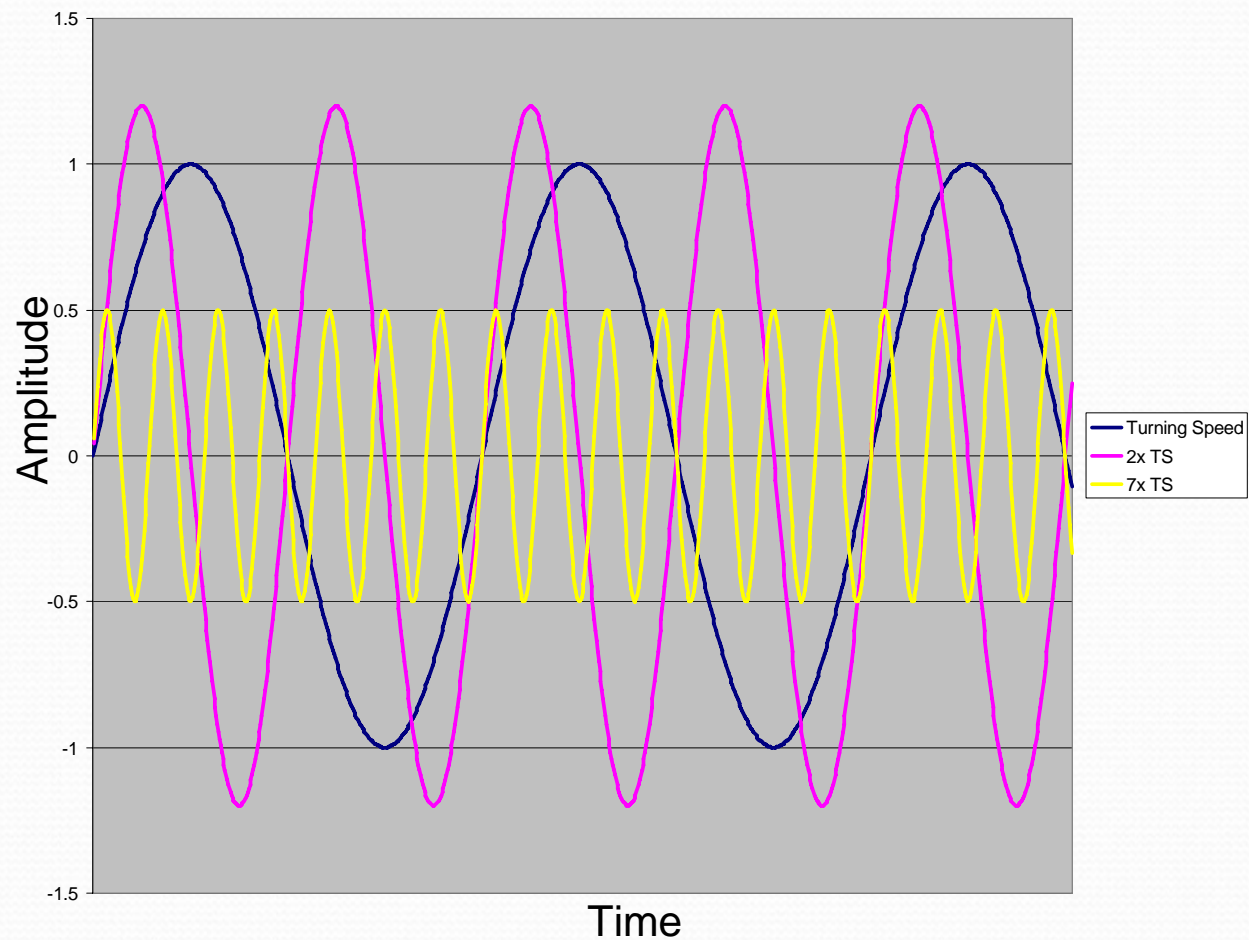
Turning Speed Time Waveform

Signal Processing



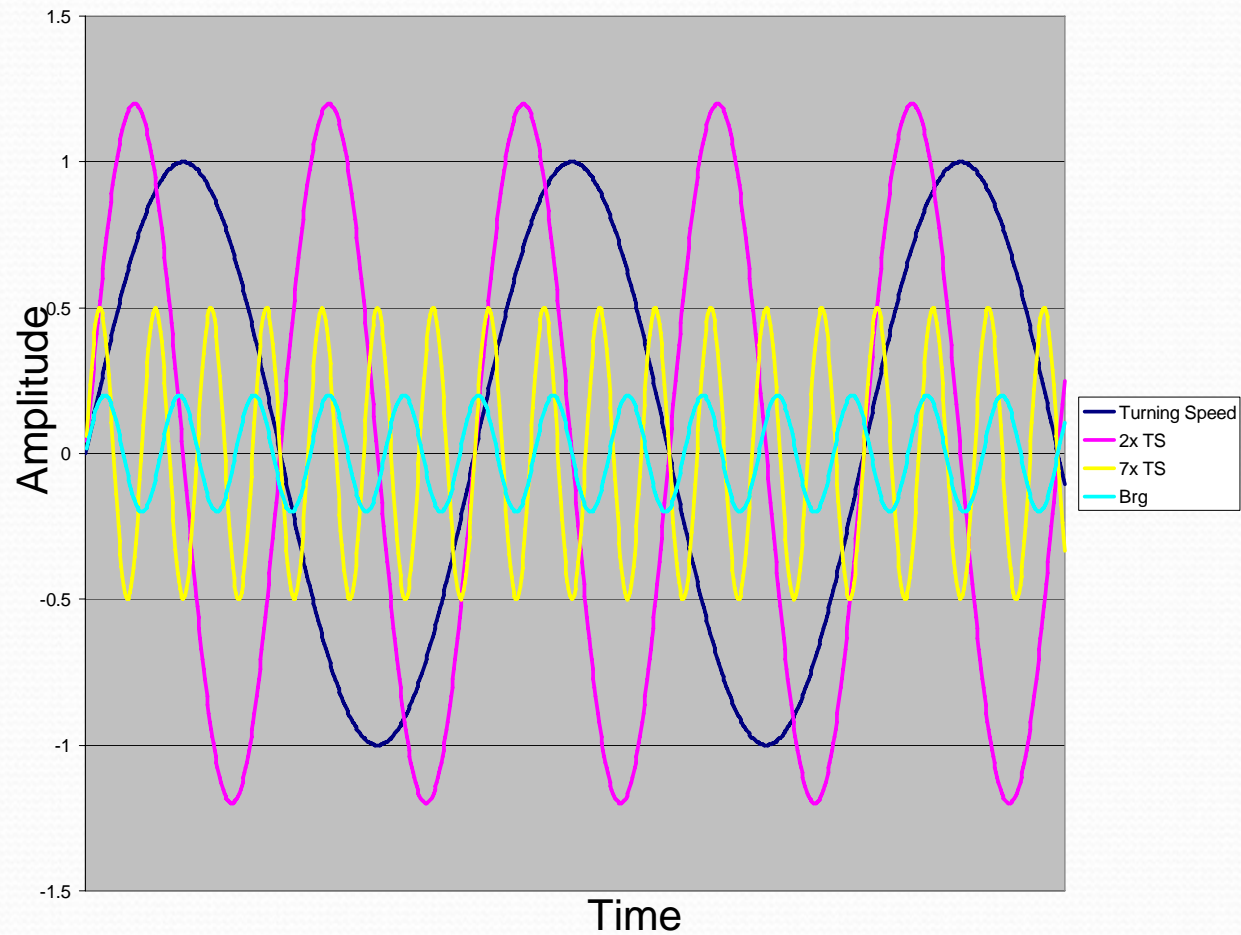
Add twice turning speed vibration

Signal Processing



Add blade pass vibration

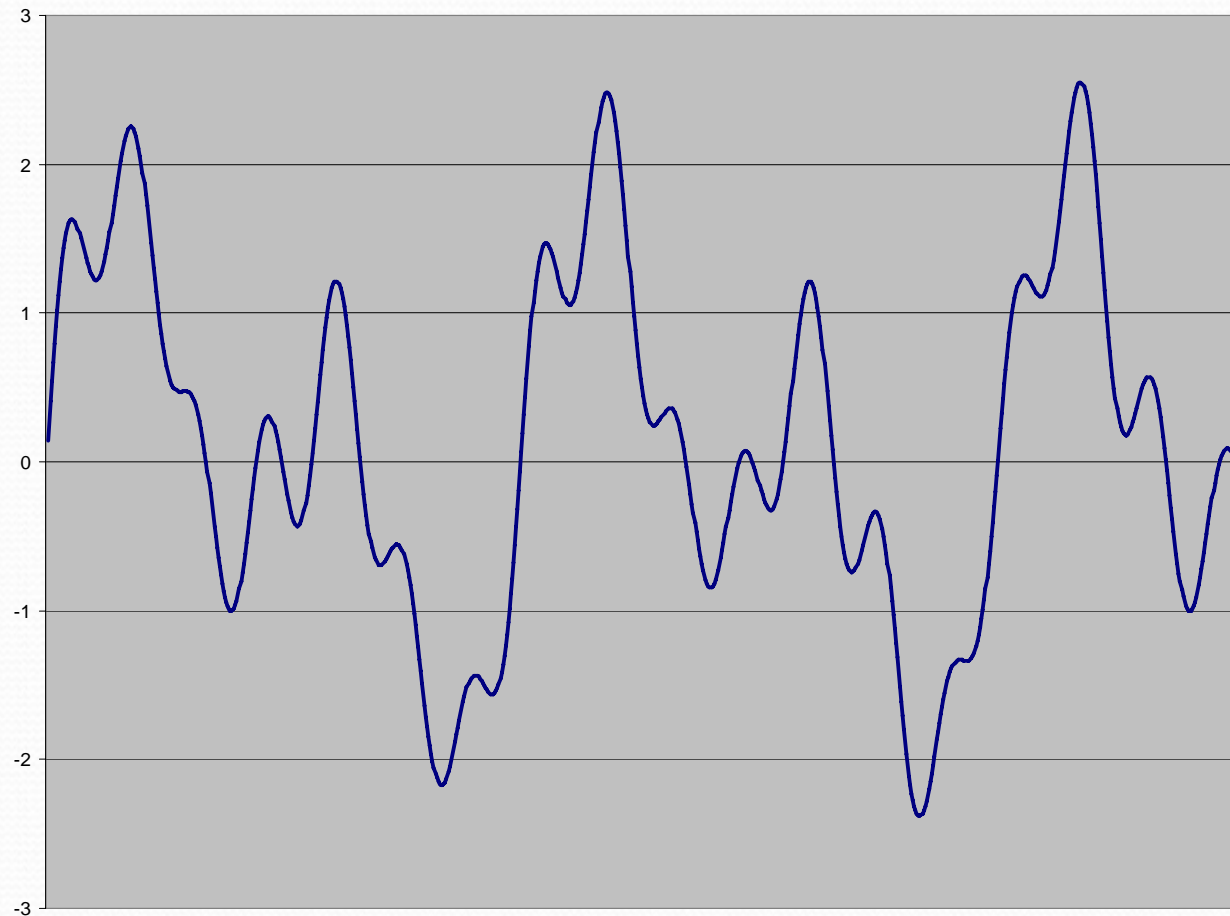
Signal Processing



Add Bearing Vibration

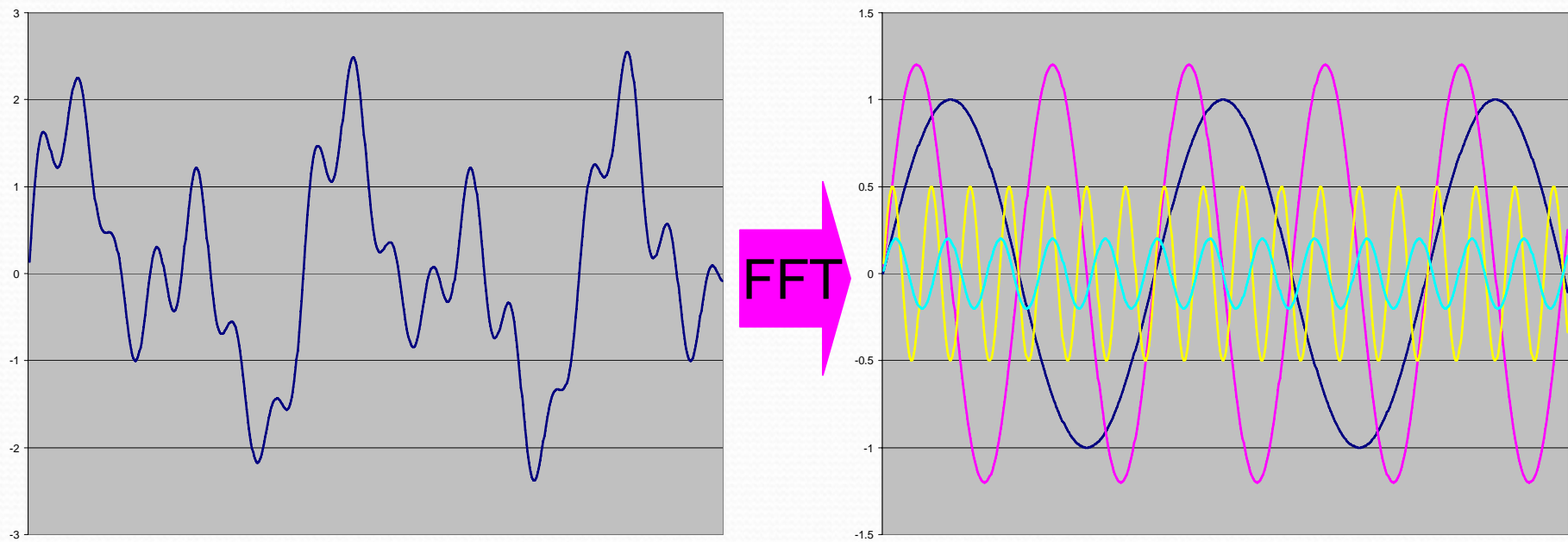
Signal Processing

Total Vibration



Signal Processing – break down complex waveform in to waveform components

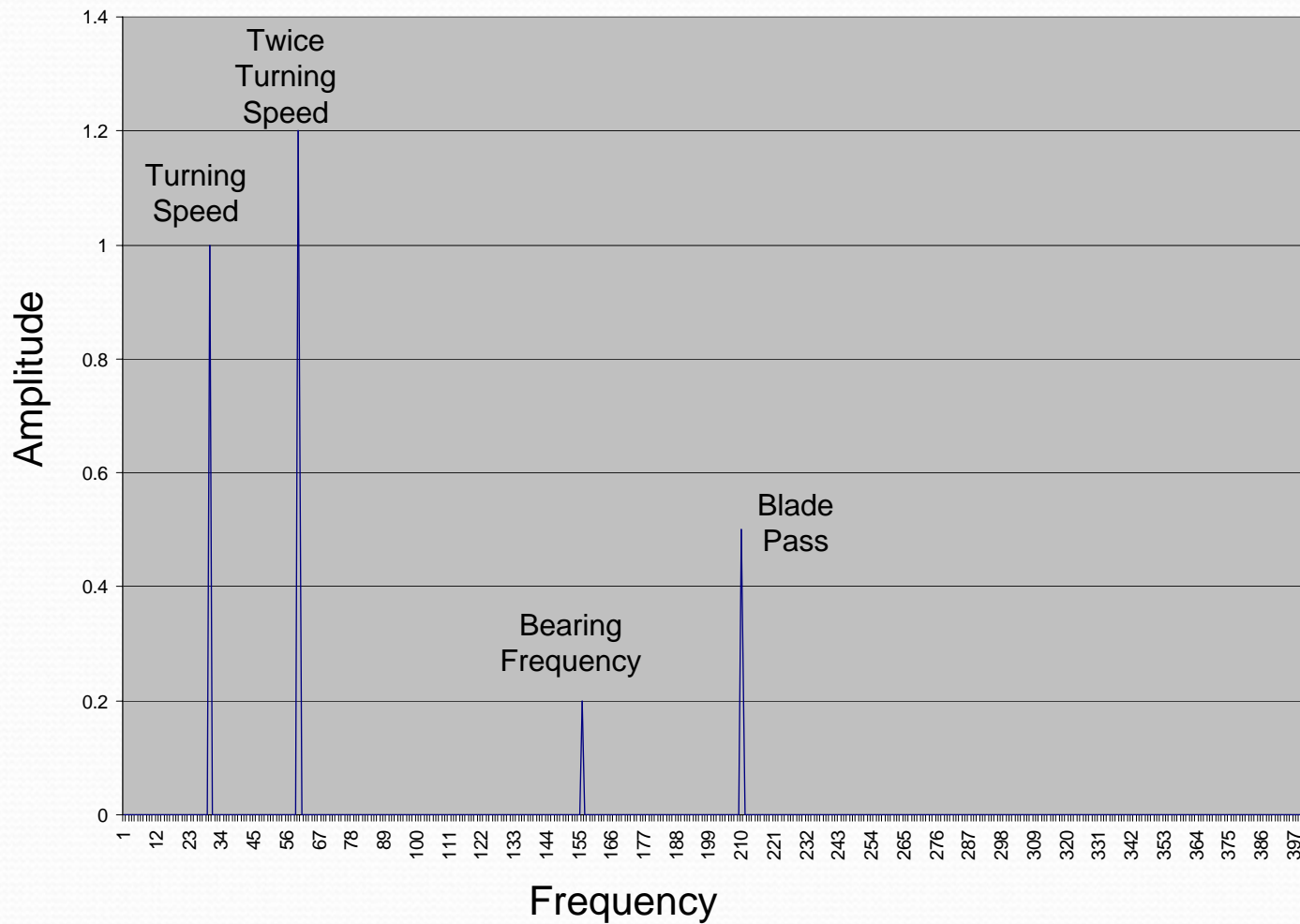
The Fast Fourier Transform (FFT) takes the complex waveform and breaks it down into the component sine waves



The amplitudes for each sine wave is then plotted at the frequency of the sine wave, creating the Spectrum

Signal Processing – The FFT or Spectrum

Spectrum (FFT)



So What can Vibration Analysis Detect?

- Detect and Track progressing stages of **Bearing Failure**
- Identify **Imbalance** and **Misalignment**
 - Vibration Analysis is used to correct Imbalance
- Identify/correct **Resonance**
- Identify **Mechanical Wear** in couplings, bearings, support structures, etc.
- Detect other defects such as:
 - Lube failure / soft foot / broken rotor bars
 - Pump cavitation, and many more...

What is a Vibration Program?

- Expertise, Technology, and Work Processes that
 - **Prevent Unexpected Downtime**
 - By assuring machines do not fail catastrophically
 - **Extend Machine Life and Optimize Performance**
 - By detecting & correcting root cause conditions that cause excessive wear
 - **Allow You To Work Efficiently**
 - By trending progressing faults and...
 - Coordinating repairs to occur at planned outages

Do the right work...

At the right time...

With the right methods...

A Few Case Histories to Get You Thinking

- Paper Mill:

- On-line vibration monitoring detected a cracked shaft
 - Press section
 - Trend increased drastically over 36 hour period
 - Would have otherwise failed catastrophically



- Offshore Oil Platform:

- On-line vibration monitoring saves compressor twice!
 - Bearing problem detected through vibration analysis.
 - Bearing was replaced.
 - New fault detected 6 hours later
 - *Thermal expansion created bearing misalignment*



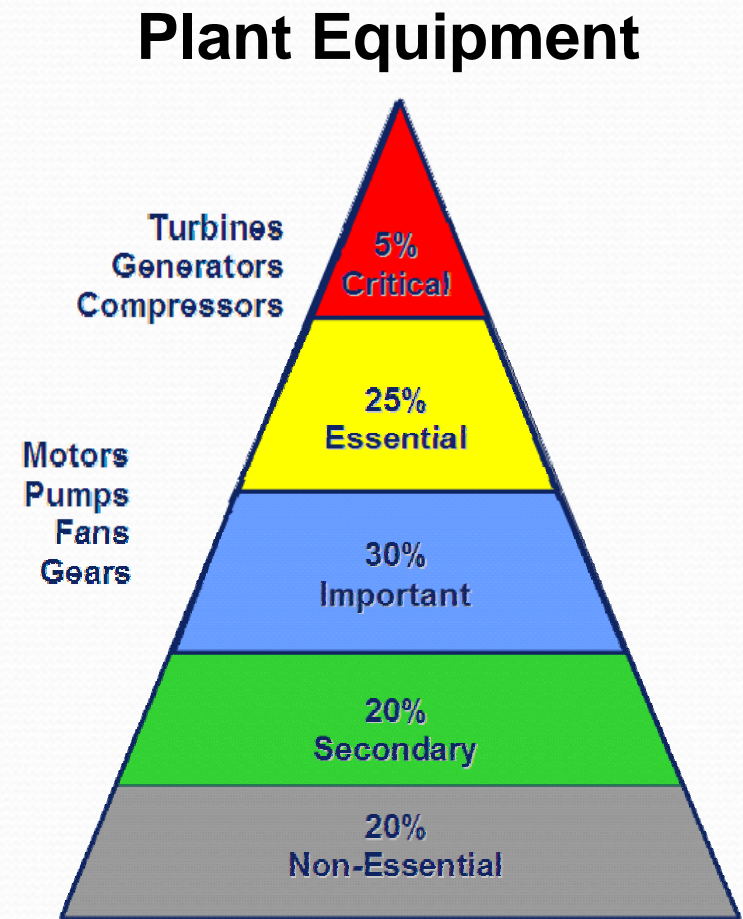
A Few Case Histories to Get You Thinking

- Cement Mill:
 - On-line vibration monitoring solves mystery
 - Air handler with intermittent high vibration
 - Resonance occurs when baffle open at ~61%.
- Power Plant:
 - On-line vibration extends maintenance intervals
 - Preventive turbine maintenance every 5 years
 - Unnecessary maintenance can induce faults!
 - Extend from 6 – 10 years with on-line monitoring
 - Average repair cost around \$1 million



Where Should Vibration Analysis be Used?

- Predictive
 - Critical to production
- Preventive
 - Support equipment
- Reactive
 - Easy/Inexpensive to replace



Establishing a Vibration Program

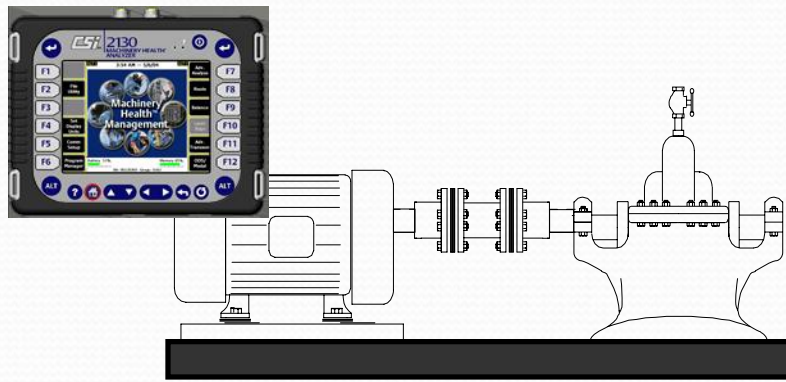
- Define program focus / resources
- Determine collection method(s)
- Create database
- Collect data
- Detect developing faults
- Diagnose nature and extent of fault
- Document business and maintenance implications

1) Define Program Focus

- Identify Critical Machines
 - Effect on production
 - Availability of back-up machine
 - Cost to repair
 - Time to repair
- Determine Resources
 - Fully in-house staffed
 - Fully out-sourced
 - Combination: Startup, Initial contract service, etc.

2) Determine Collection Method(s)

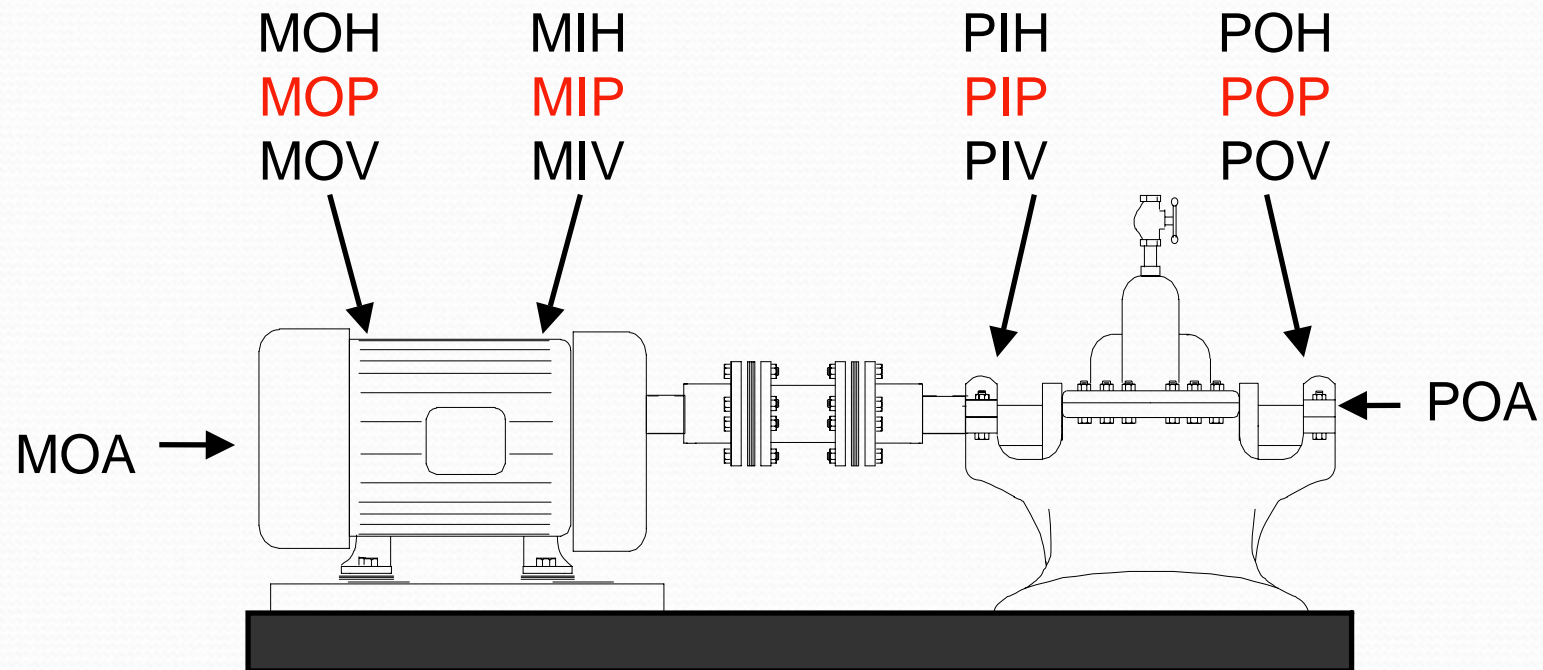
- Route-based periodic
 - General plant equipment
 - Walk around survey
 - Manual measurement
 - Monthly reading typical
 - Readily accessible
- Online monitoring
 - Critical equipment
 - Installed sensors
 - Automatic monitoring
 - Define measurement interval
 - Inaccessible or hazardous areas



3) Create Database

- Enter machine configuration information
 - Machine ID (asset code) and Description
 - Machine Design info, Operating Speed, etc.
- Define measurement points
 - Point ID (identification) and Description
 - Sensor Type (accelerometer)
 - Analysis Parameters (how to analyze signal)
 - Alarm Limits (allowable amount of vibration)

Data Collection Points - Nomenclature



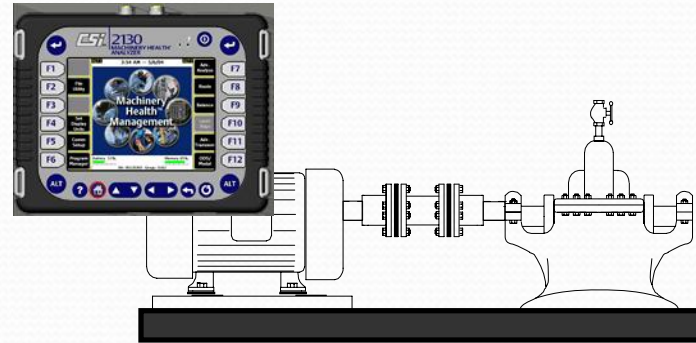
Standard: 2 vibration directions per bearing + 1 axial per shaft

Add 1 PeakVue[®] point per anti-friction bearing

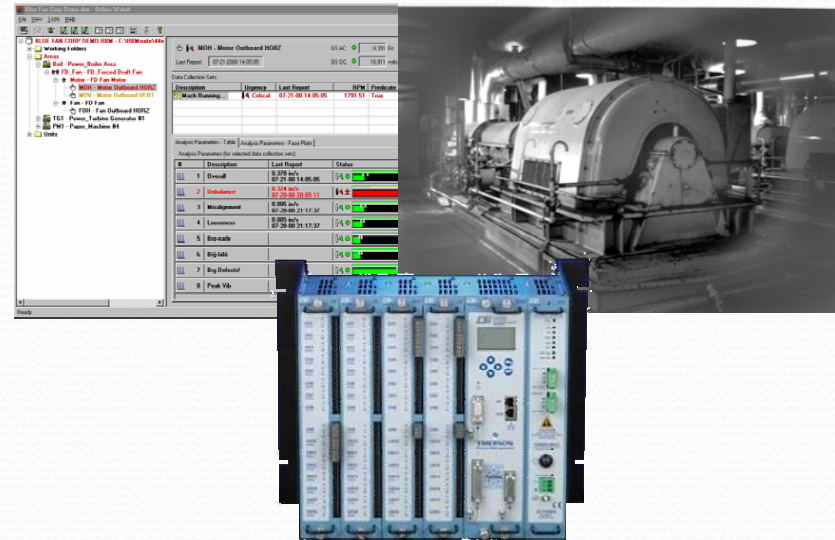
MOH = Motor Outboard Horizontal

Collect Data (Survey)

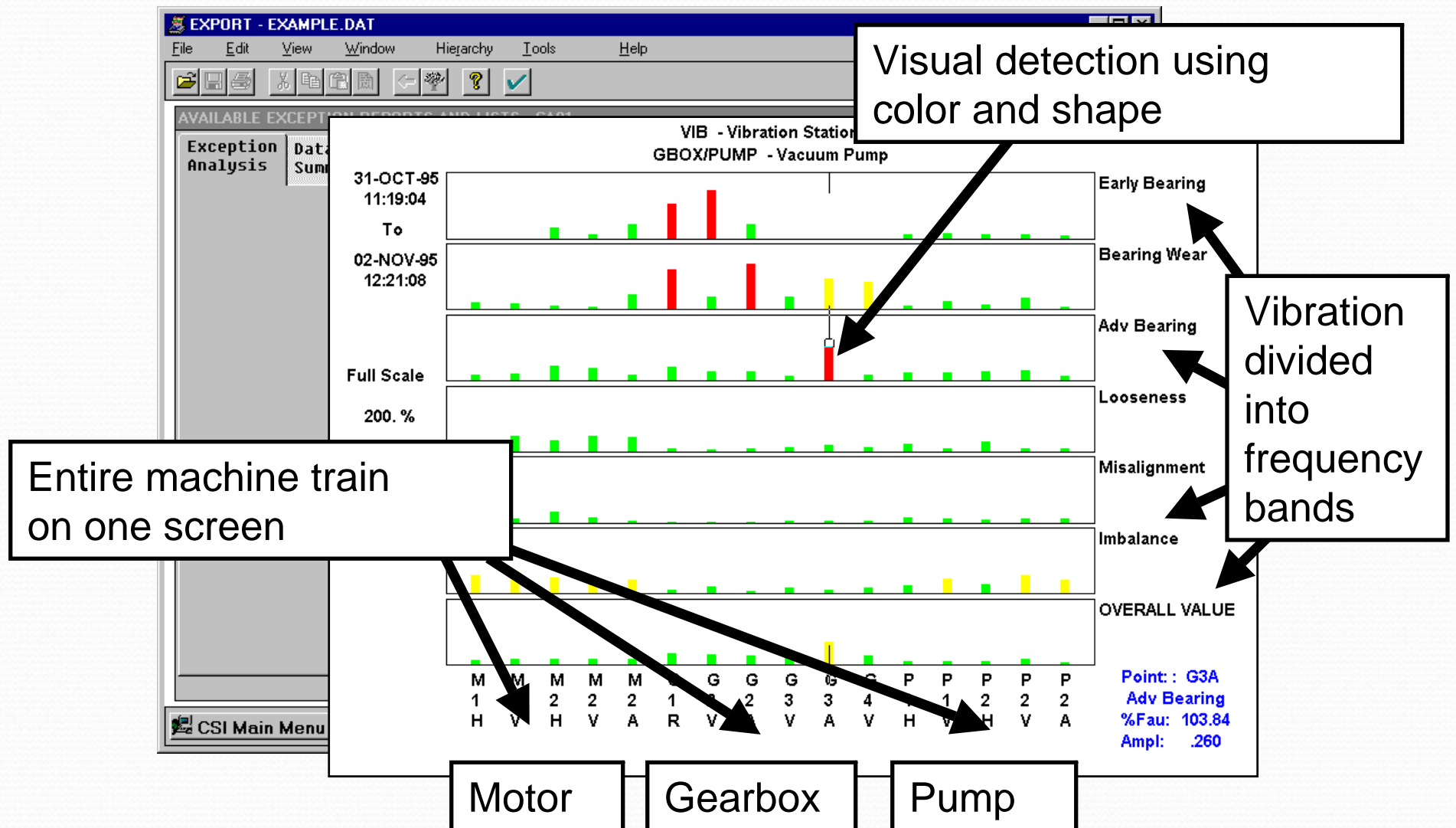
- 1) Periodic survey with walk-around Portable Analyzer



- 2) Continuous survey with online monitoring



5) Detect Developing Faults



6) Diagnose Nature of Fault

- Each machine fault generates a specific vibration pattern (Bearings, Belts, etc.)
- A single vibration measurement provides information about multiple components
- The frequency of the vibration is determined by the machine design and operating speed

6) Diagnose Nature of Fault

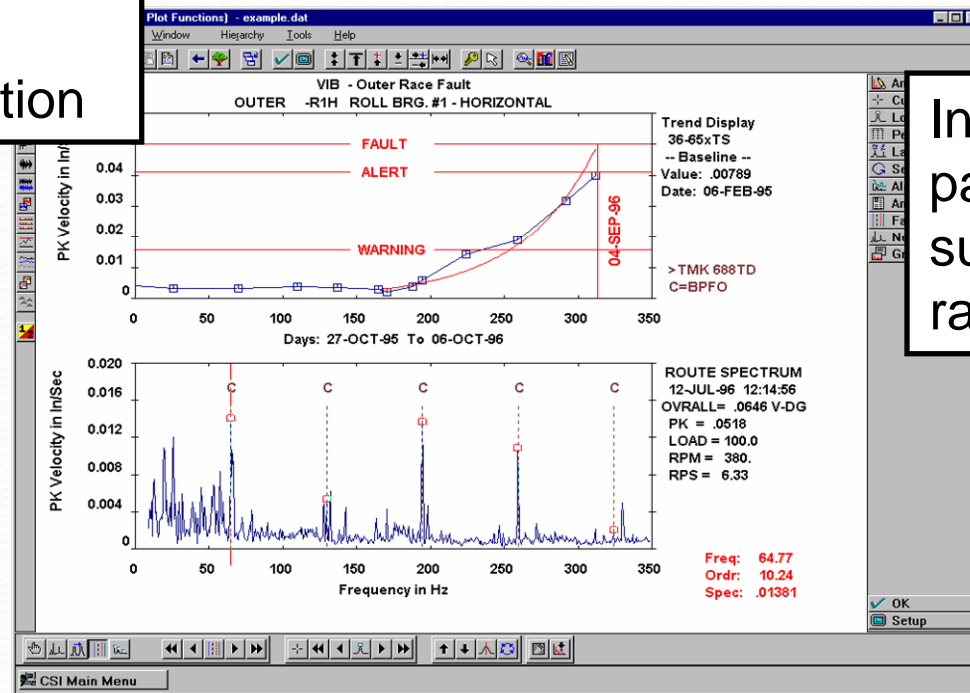
Knowing the accurate machine speed and phase is *important* for vibration analysis.



A tachometer is required to determine machine speed and phase.

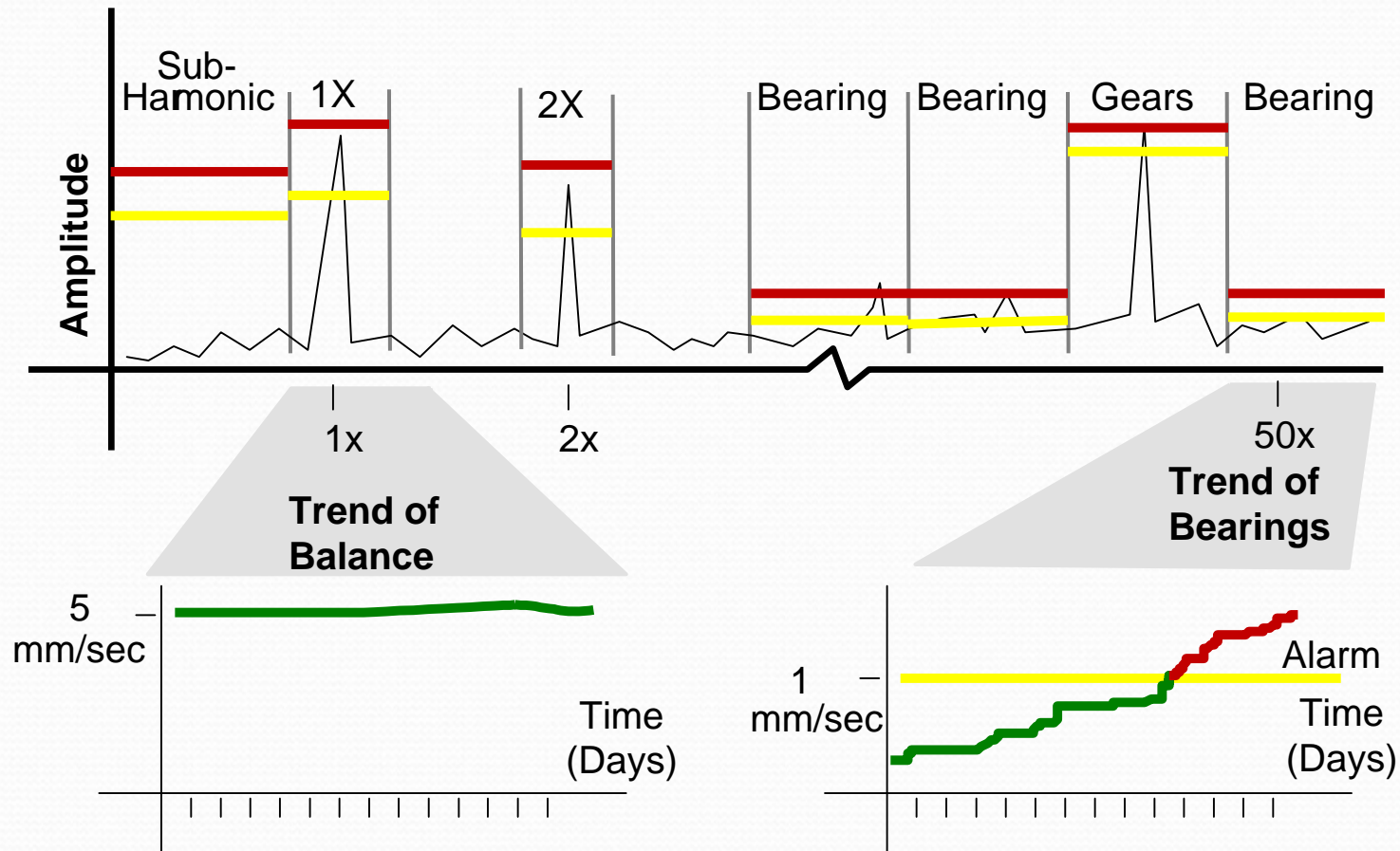
6) Diagnose Nature of Fault

Trend shows rate of advancement for fault in question



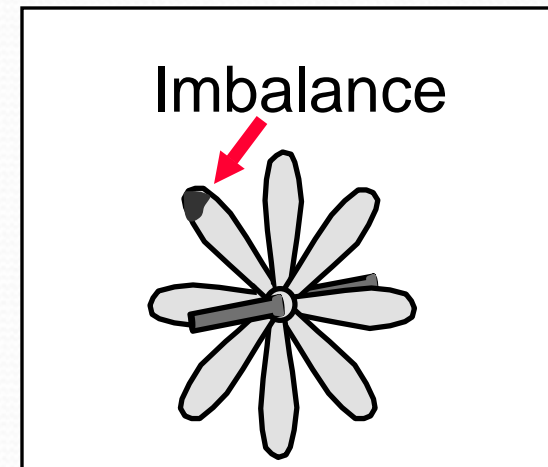
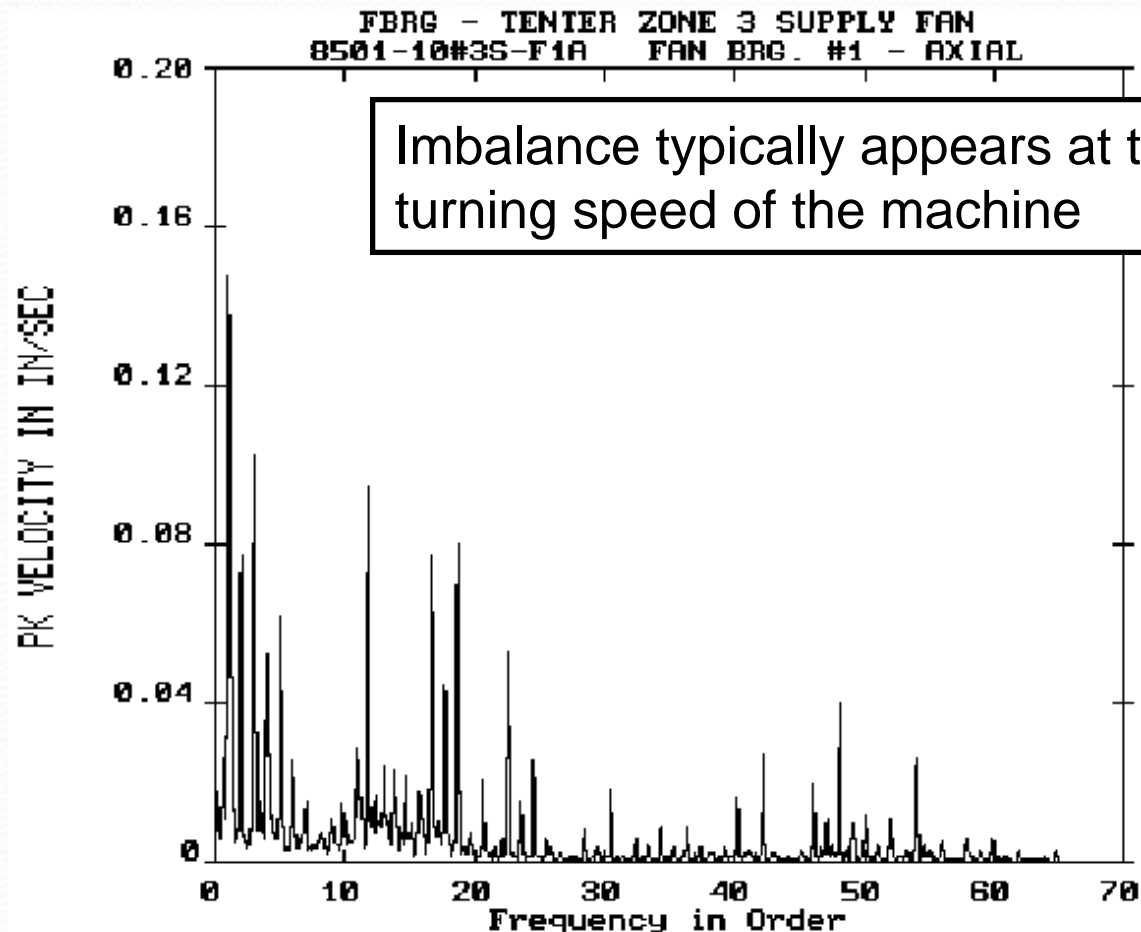
Individual trend parameter covers suspect frequency range

Frequency Band Alarming

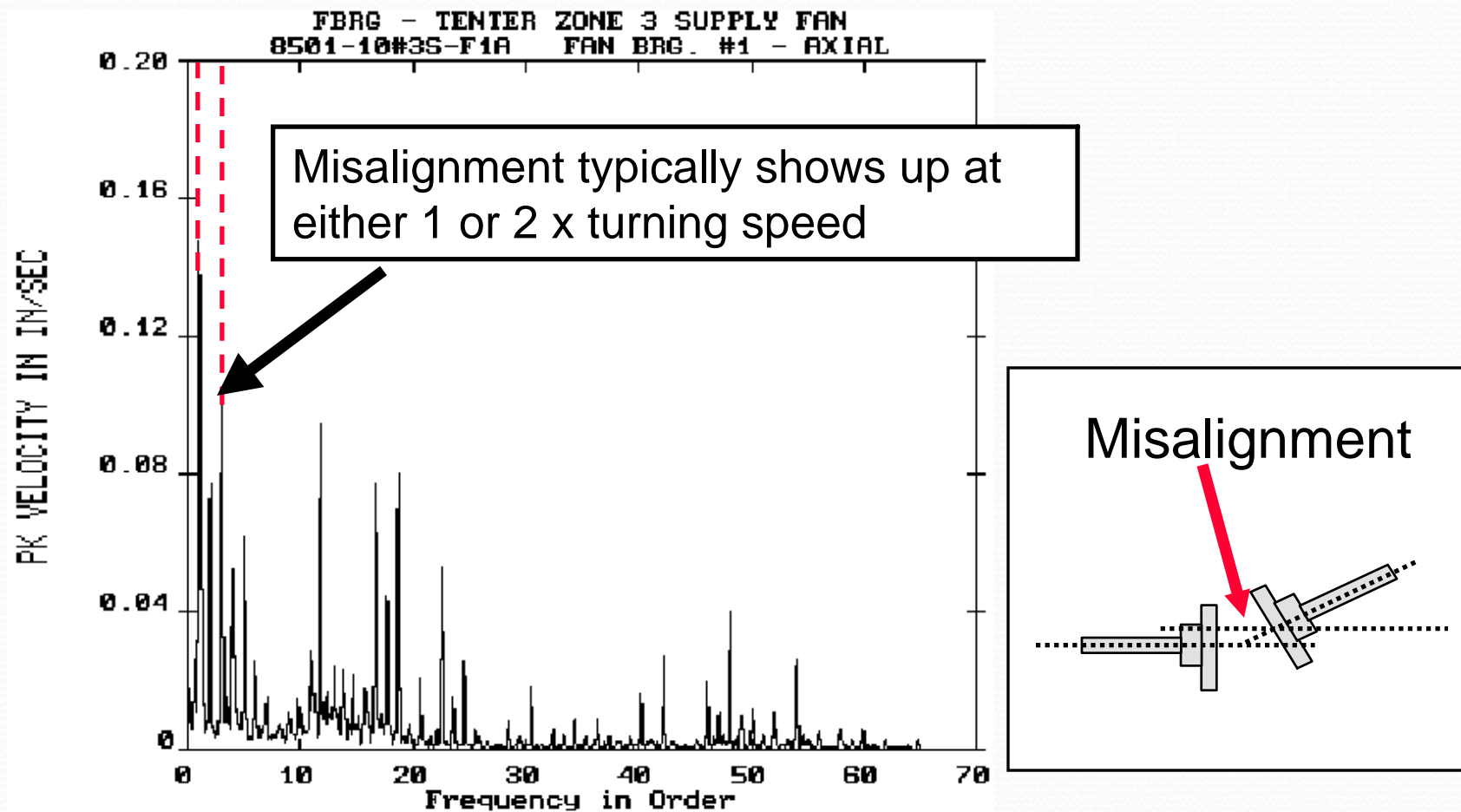


Alert and Fault alarms for each parameter

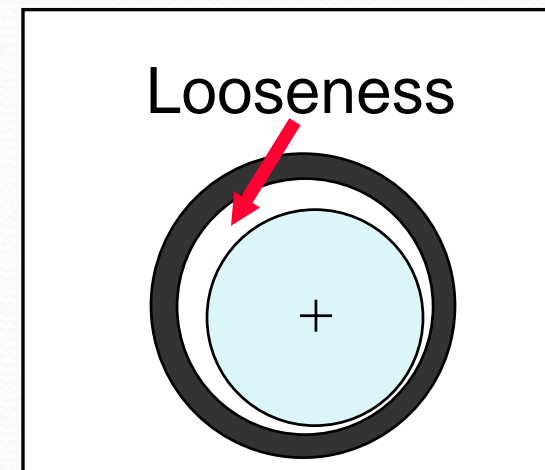
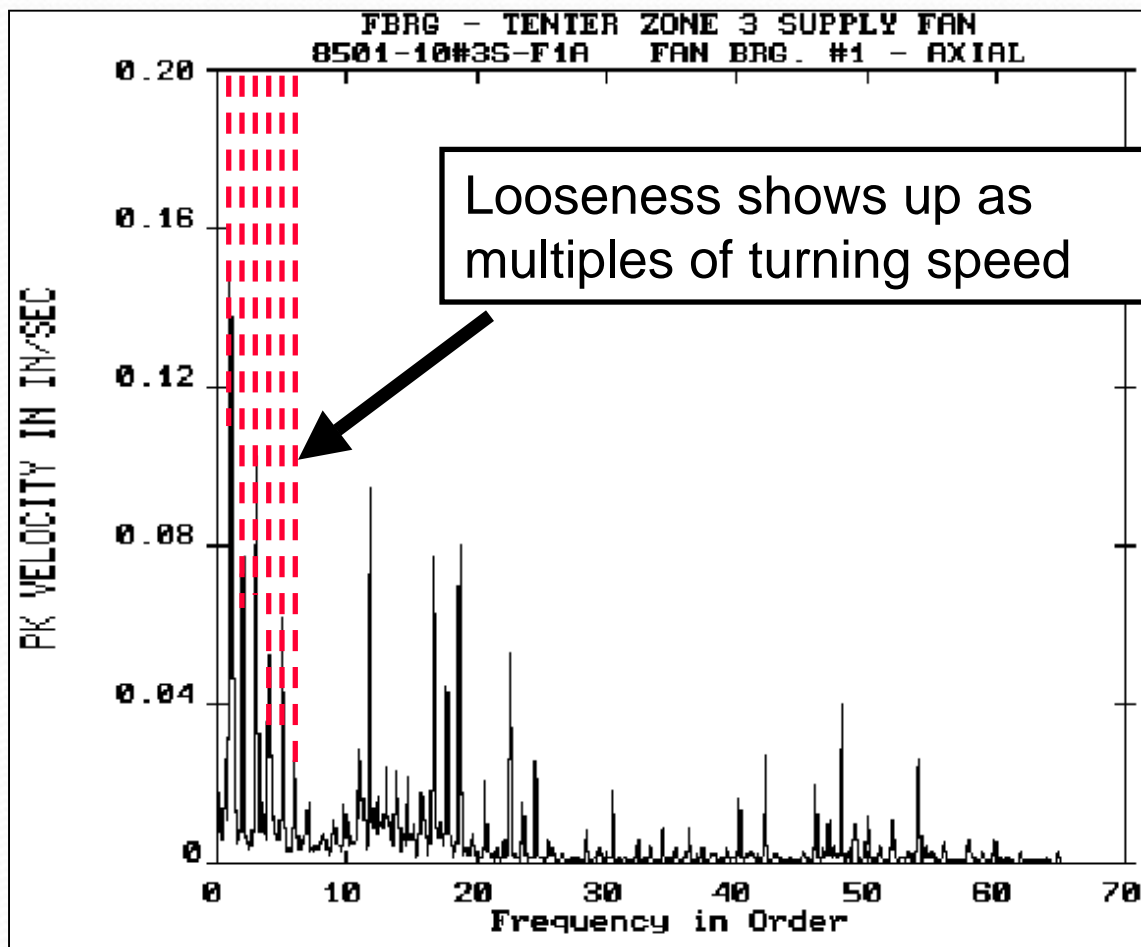
6) Diagnose Nature of Fault



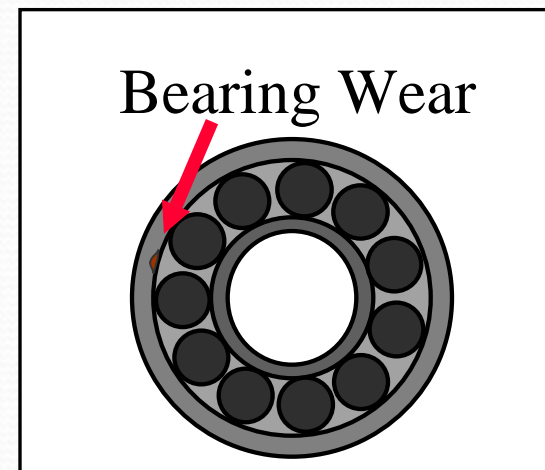
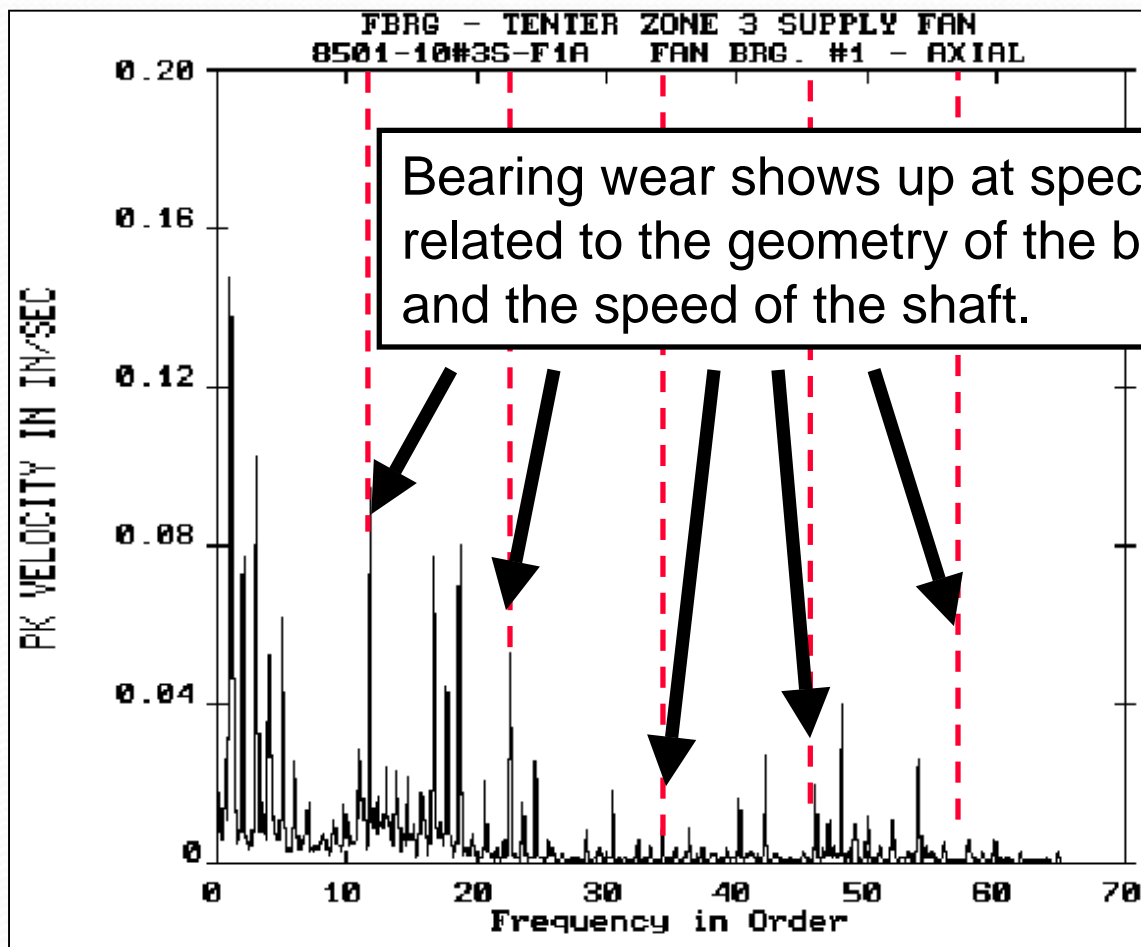
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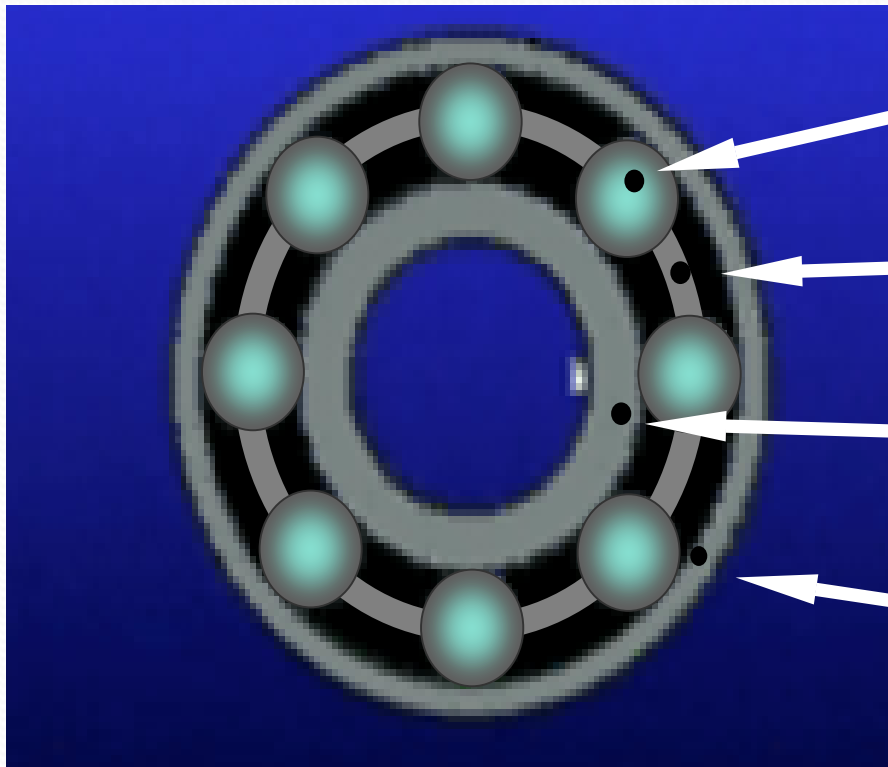


6) Diagnose Nature of Fault



Roller Bearing Faults

Four different bearing frequencies



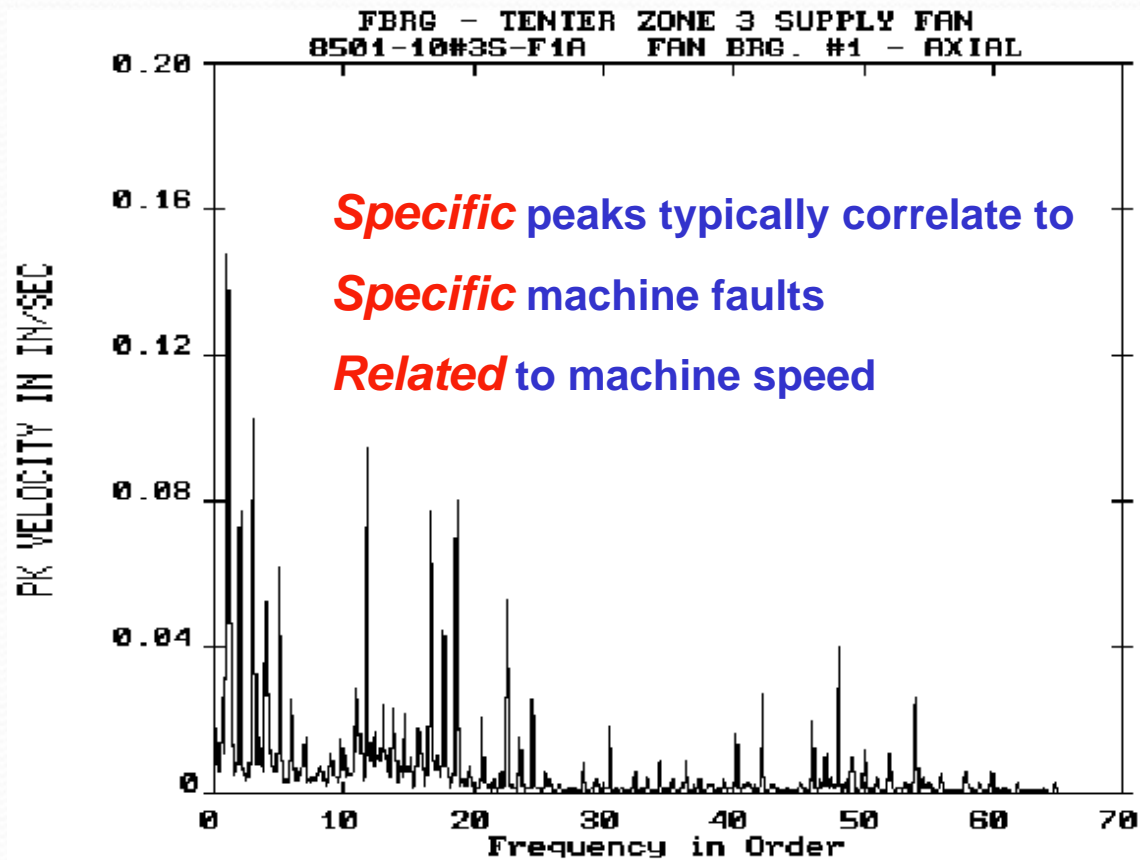
**Ball Spin Frequency
(BSF)**

**Fundamental Train
Frequency
(FTF)**

**Ball Pass Frequency
Inner Race
(BPFI)**

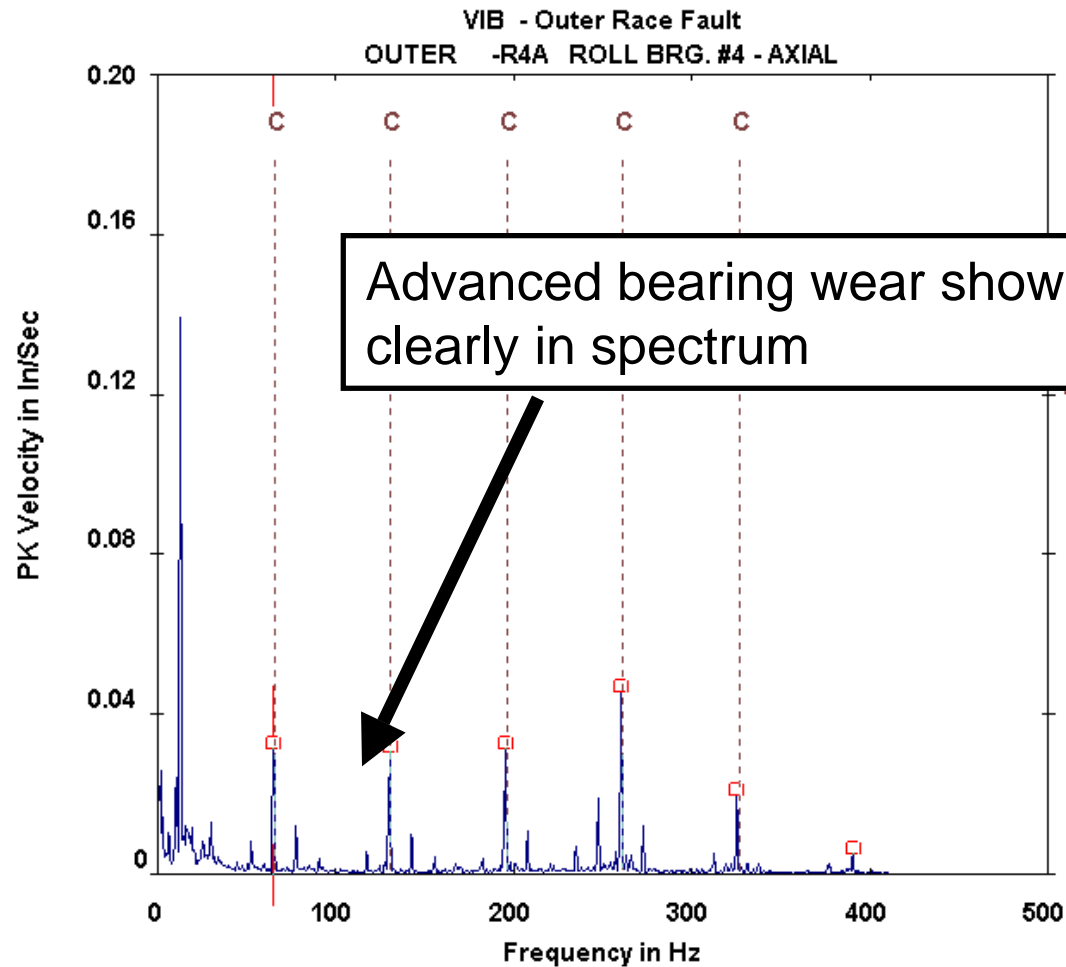
**Ball Pass Frequency
Outer Race
(BPFO)**

A Typical FFT Spectrum

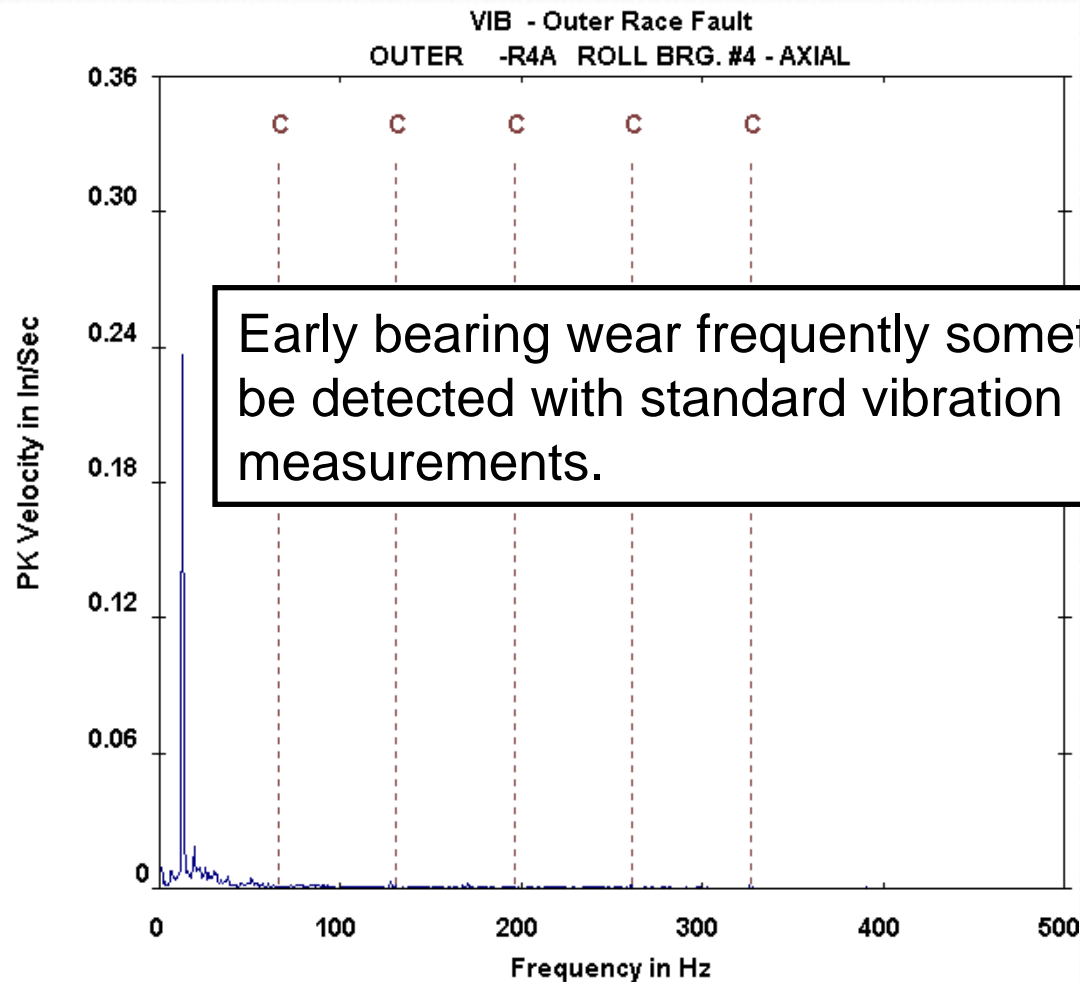


Need Spectrum Analyzer for diagnostics, not just Overall vibration meter

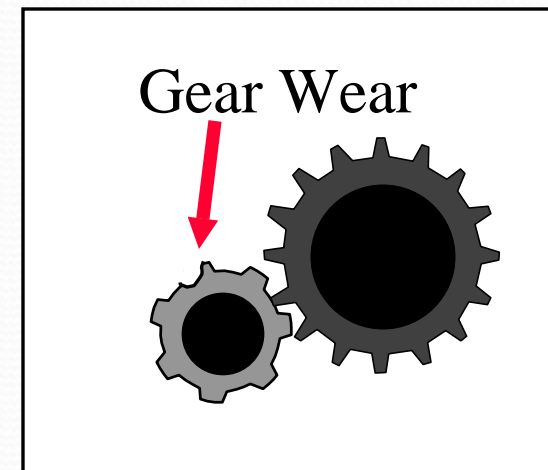
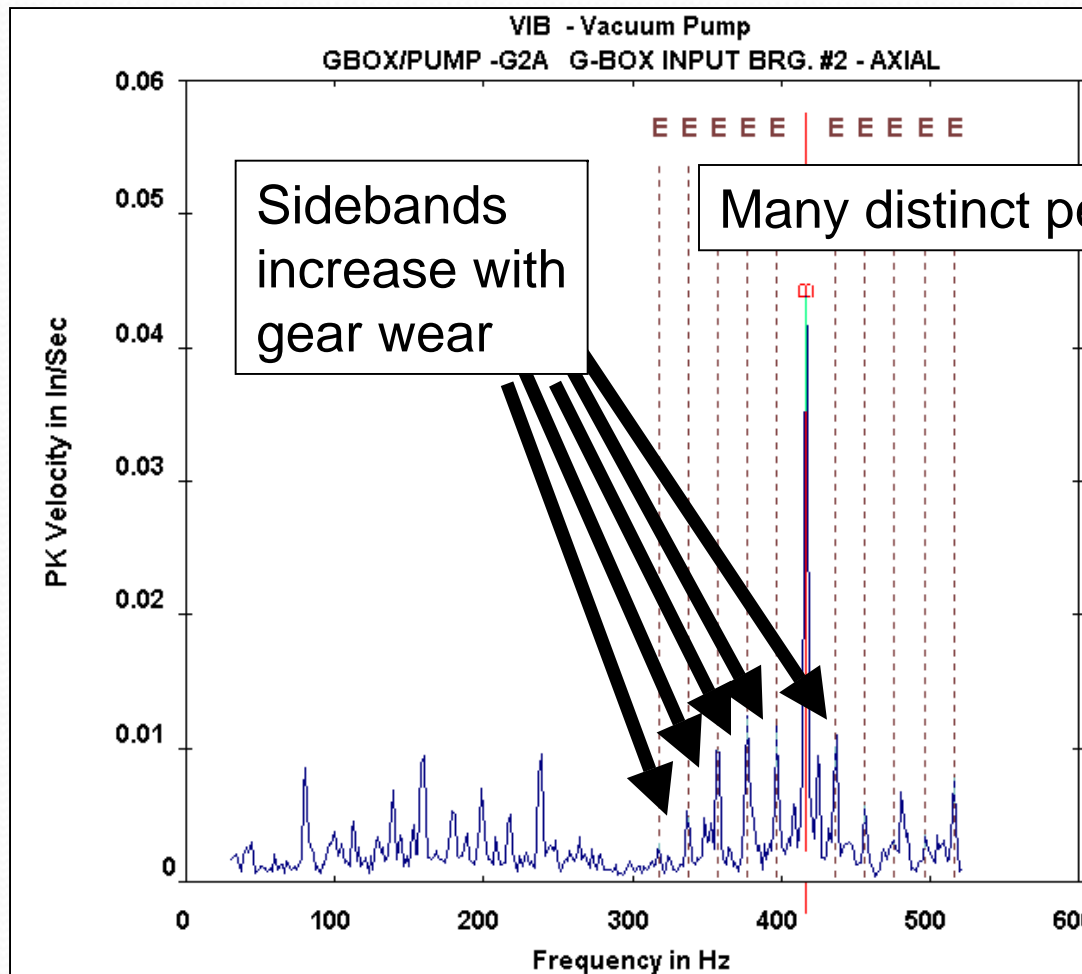
Actual Outer Race Defect



Onset of Outer Race Defect

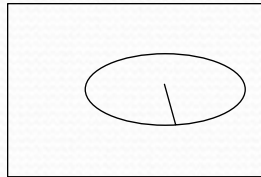


Gear Mesh Fault

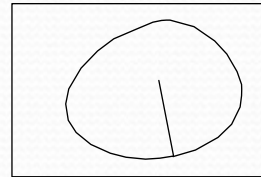


Examples of Orbits

Misalignment,
Resonance, Wear



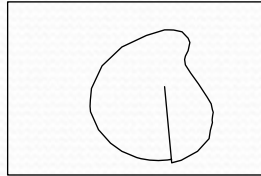
Ellipse



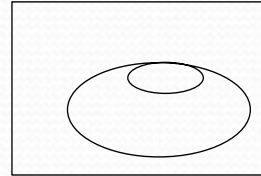
Truncation

Misalignment

Misalignment



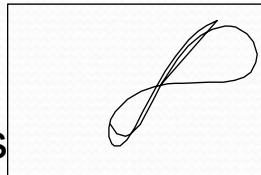
"Banana"



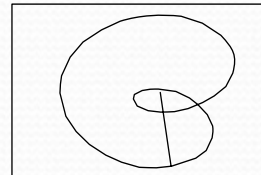
Inside ellipse

Shaft rub or
mechanical looseness

Misalignment
and other problems

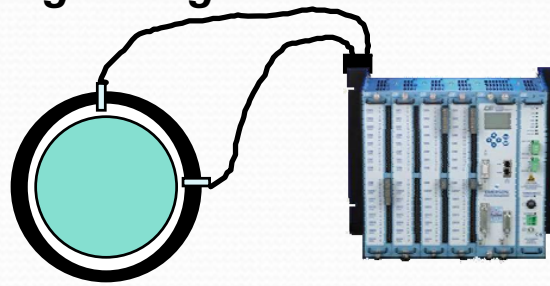


"Figure Eight"



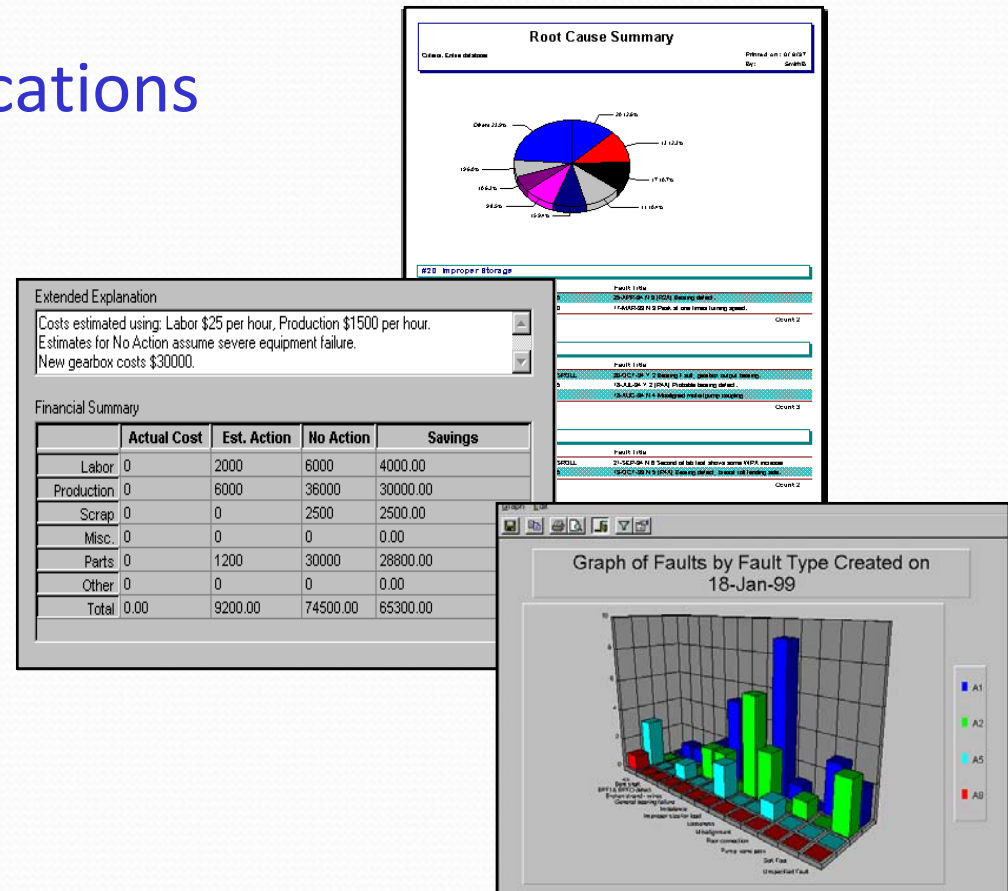
Inner loop

Sub-synchronous whirl



7) Document Business & Maintenance Implications

- Document:
 - Diagnoses
 - Recommendations
 - Accuracy
 - Reoccurring faults
 - Production gains
 - Cost savings
 - Financial impact



Summary: Key Points in a Vibration Program

- Expertise, Technology, and Work Processes that
 - **Prevent Unexpected Downtime**
 - By assuring machines do not fail catastrophically
 - **Extend Machine Life and Optimize Performance**
 - By detecting & correcting root cause conditions that cause excessive wear
 - **Allow You to Work Efficiently**
 - By trending progressing faults and...
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